British Heart Journal, 1977, **39**, 1234–1238

Coronary arteries in d-transposition
A necropsy study of reimplantation

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The coronary arteries are a major concern in anatomical correction of d-transposition of the great arteries. This necropsy study was undertaken to assess the feasibility of direct bilateral reimplantation as described by Jatene et al. *This seemed possible in only 30 per cent of 100 cases, and furthermore was related to the type of coronary artery pattern.*

Direct anatomical correction of d-transposition of the great arteries has stimulated increasing interest since the first favourable surgical results were reported (Jatene *et al.*, 1976). However, initial enthusiasm has been tempered by several failures. Poor results have been explained by high pulmonary vascular resistance in cases with an open septum (Jatene *et al.*, 1976) and by poor left ventricular function in cases with an intact ventricular septum (Major *et al.*, 1976). There are also technical problems related to how and where to cut the aorta and the pulmonary arteries to avoid tension and compression, and to the reimplantation of the coronary arteries.

Balderman *et al.* (1974) studied the anatomical mobility of the coronary arteries in 58 hearts with transposition of the great arteries. Coronary artery pattern in all their specimens belonged to type 1 of the Shaher and Puddu classification (Shaher and Puddu, 1966). The authors found that both coronary arteries were movable in 48 per cent of the cases, and concluded that coronary artery anatomy in transposition of the great arteries was such that direct switching of the vessels to achieve anatomical correction was possible.

To investigate this problem further, coronary artery anatomy was studied in 100 necropsy cases of transposition of the great arteries under 4 months of age, belonging to most types of the Shaher classification. Satisfactory direct reimplantation of both coronary arteries as described by Jatene *et al.* (1976) seemed possible in only 30 per cent of the cases.

Material and methods

The study comprised 100 formalin preserved hearts of infants with transposition of the great arteries, dying under 4 months of age; poorly preserved or damaged specimens were excluded.[1]

Drawings of the initial portion of the coronary arteries were made, to study the disposition of the first branches. Measurements were then made from the ostium to the first branch of each artery. Finally, the origins of the coronary arteries were dissected and the ostia excised with a ring of adjacent aortic wall and brought to the nearest suitable reimplantation site on the pulmonary artery. Excessive traction or kinking was avoided either by division of the first branch, or by interposition of a graft.

Results

Coronary artery patterns could be classified as follows (Fig. 1).

Group 1: 65 cases. The left coronary artery arises from a single ostium above the left sinus and divides into the anterior descending and the left circumflex arteries. The right coronary artery arises from a single ostium above the posterior sinus and divides into descending and marginal arteries.

Group 2: 22 cases. The left sinus gives rise to the left anterior descending artery alone. The left circumflex and right coronary arteries arise from the posterior sinus.

Group 3: 6 cases. The posterior sinus gives rise to all 3 major arteries. In 4 of the cases, there was also a vessel arising from a small ostium above the left sinus, with branches to the interventricular septum and the adjacent anterior wall of the left and right ventricles.

Group 4: 3 cases. The left sinus gives rise to all 3 major arteries. In all 3 cases there was also a

Received for publication 3 March 1977

[1] All specimens were studied at the Department of Pediatric Cardiology, Pr Ribiere, Hopital Parrot-Bicetre, Paris, France.

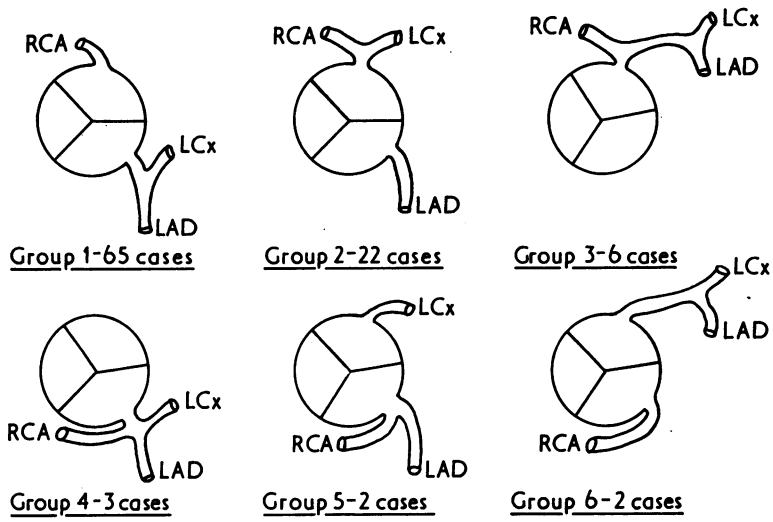

Fig. 1 *Coronary arteries in 100 cases of d-transposition of the great arteries. LAD, left anterior descending artery; LCx, left circumflex; RCA, right coronary artery.*

vessel arising from tiny posterior ostium, with small branches to the left and right atria and interatrial septum.

Group 5: 2 cases. The left sinus gives rise to the left anterior descending and right coronary arteries. The left circumflex artery alone arises from a posterior ostium.

Group 6: 2 cases. The left sinus gives rise to the right coronary artery. The posterior sinus gives rise to a long left coronary artery which divides into anterior descending and left circumflex arteries on the left side of the pulmonary artery.

REIMPLANTATION IN GROUP I

Reimplantation of left coronary artery

Direct reimplantation was possible in 36 of the 65 cases. In 15 cases it was necessary to ligate and divide the first branch artery to make it possible to reimplant the ostium. In 14 cases interposition of a graft was necessary. Several factors determined the feasibility of reimplantation.

(1) The length of the left main coronary artery before dividing into anterior descending and left circumflex arteries, (2) the distribution of the first branch arteries which arise before the division into anterior descending and left circumflex arteries, and (3) the exact position of the pulmonary artery.

In 18 cases the left main coronary artery had no branches before dividing into the anterior descending and left circumflex arteries, and varied from 1 to 8 mm in length (Table 1). In 47 cases the left coronary artery gave rise to branches directed towards the right before or at the point of division into anterior descending and left circumflex (Table 2); these tend to anchor the initial segment of the left coronary artery. They usually cause no difficulty if they are very oblique or arise close to the origin of anterior descending artery. They seriously interfere with direct reimplantation when they are perpendicular to the left coronary artery or close to the coronary ostium (Fig. 2).

The exact position of the pulmonary artery is

Table 1 *Group 1: Length of left main coronary artery in 18 cases with no branches before division into anterior descending and circumflex arteries.*

Length (mm)	*No. of cases*
1	1
2	1
3	7
4	3
5	3
6	2
8	1

Table 2 *Group 1: Length of left main coronary artery before first branch in 47 cases*

Length (mm)	*No. of cases*
0	5
0·5	6
1	5
2	13
3	8
4	5
5	3
6	1
7	1

also relevant. This may be relatively posterior or may be close to the origin of the left coronary artery, allowing even a short initial segment to be reimplanted.

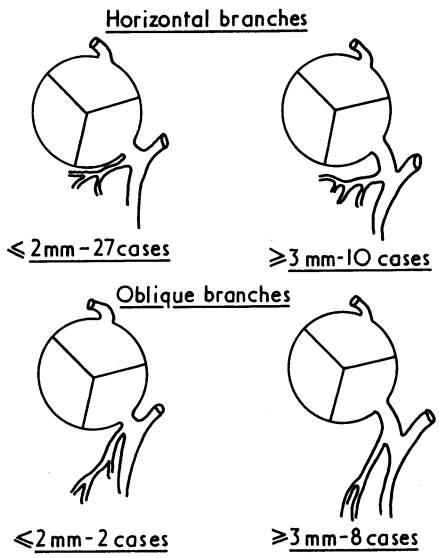

Fig. 2 *Left coronary artery in group 1. Regrouping of 47 cases, in whom first branch arose before division into circumflex and anterior descending arteries, according to orientation and distance from ostium of first branches.*

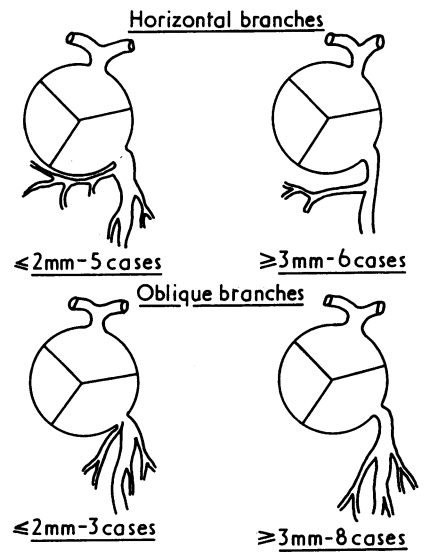

Fig. 3 *Left anterior descending coronary artery in group 2. Orientation and distance from ostium of first branches.*

Reimplantation of right coronary artery

The free initial segment before the first branch artery, either to the atrium or the right marginal artery, was between 0·5 and 10 mm in length (Table 3). Direct reimplantation was possible in 48 cases. When the first branch of the right coronary artery was to the right atrium (31 cases), direct reimplantation was possible in 20 cases, division of the first branch was necessary in 10, and interposition of a graft in 1. When the first branch was the marginal artery, direct reimplantation was possible in 28, but interposition of a graft was necessary in the other 6 cases.

REIMPLANTATION IN GROUP 2

Reimplantation of left anterior descending artery

Direct reimplantation was possible in 12 of the 22 cases. In 4 cases the first branch artery had to be divided. In 6 cases interposition of a graft was necessary. The possibility of direct reimplantation depends essentially on the position of first branches as described for group 1 (Table 4, Fig. 3).

Reimplantation of right coronary artery

In this group the right coronary artery divided into the posterior descending and left circumflex arteries. The division was immediate, with 2 adjacent

Table 3 *Group 1: Distance from ostium of right coronary artery to first branch*

Length (mm)	*No. of cases*
1	4
2	6
3	11
4	17
5	7
6	8
7	5
8	3
9	1
10	3

Table 4 *Group 2: Distance from ostium of left anterior descending artery to first branch*

Length (mm)	*No. of cases*
0	2
0·5	2
1	1
2	3
3	5
4	2
5	2
6	1
7	2
10	2

posterior ostia, in 6 hearts. The distance between the ostium and the division varied between 0 and 6 mm (Table 5). A small branch to the atrial wall and septum arose from the bifurcation into the posterior descending and left circumflex arteries in 8 cases.

Direct implantation seemed possible in only 1 case. Interposition of a graft was necessary in the other 21 cases. The obstacle to direct reimplantation is that when the ostium is detached and displaced towards the pulmonary artery on the left, the left circumflex artery is angulated and furthermore is compressed when the initial portion of the pulmonary artery is expanded. To avoid this, the artery should be dissected only from the ostium to the bifurcation, without mobilising the left circumflex or the posterior descending arteries, and a small graft placed between the detached ostium and the pulmonary artery 1 to 1·5 cm higher.

REIMPLANTATION IN GROUP 3

In this group all 3 major arteries arose from the posterior sinus. Interposition of a graft was necessary in all 6 cases for the same reasons as in the preceding group. In 4 cases there was also an ostium in the left sinus which could be reimplanted directly in 2, and needed a graft in 2.

Table 5 *Group 2: Distance from posterior ostium to division into left circumflex and right coronary arteries*

Length (mm)	*No. of cases*
0	6
0·5	4
1	3
2	3
3	2
4	1
5	1
6	1

REIMPLANTATION IN GROUP 4

In this group it was the left sinus that gave rise to the 3 major arteries. Displacing the ostium towards the pulmonary artery was limited by the right coronary artery and a graft was, therefore, necessary in all 3 cases. There was also a tiny posterior ostium in each case, for which there appeared to be no satisfactory solution.

REIMPLANTATION IN GROUP 5

In both cases, the ostium in the left sinus, from which the left anterior descending and right coronary arteries arose, could be directly reimplanted into the pulmonary artery. The posterior ostium giving rise to the left circumflex artery could also be reimplanted directly in both cases.

REIMPLANTATION IN GROUP 6

The ostium in the left sinus giving rise to the right coronary artery could be reimplanted directly in 1 case, but a graft was necessary in the other. The posterior ostium gave rise to the left coronary artery and divided into anterior descending and left circumflex arteries on the left side of the pulmonary artery; direct reimplantation was possible in both cases.

Discussion

This study was undertaken to evaluate the difficulties which would be encountered with coronary artery reimplantation during anatomical correction of transposition of the great arteries and to define particular problems related to the different coronary artery patterns. Reimplantation is not always easy and technical problems will certainly arise and be responsible for many failures.

In the 100 cases of transposition of the great

Table 6 *Reimplantation of coronary arteries in 100 cases of d-transposition*

Group	*No. of cases*	*Ostium*	*Arteries*	*Reimplantation*			
				Direct	*Division of early branch*	*Interposed graft*	*Impossible*
1	65	L sinus	LCA (LAD and LCx)	36	15	14	0
		Posterior sinus	RCA	48	10	7	0
2	22	L sinus	LAD	12	4	6	0
		Posterior sinus	RCA and LCx	1	0	21	0
3	6	Posterior sinus	LCA and RCA	0	0	6	0
		L sinus (4 cases only)	small branches	2	0	2	0
4	3	L sinus	LCA and RCA	0	0	3	0
		Posterior sinus	small branches	0	0	0	3
5	2	L sinus	LAD and RCA	2	0	0	0
		Posterior sinus	LCx	2	0	0	0
6	2	L sinus	RCA	1	0	1	0
		Posterior sinus	LCA	2	0	0	0
Total	100			106	29	60	3

arteries studied here, direct bilateral reimplantation was possible in only 30 cases: 26 were in group 1, 1 in group 2, 2 in group 5, and 1 in group 6. Bilateral grafts were necessary in 9 cases: 1 in group 1, 6 in group 2, and 2 in group 3. Direct reimplantation was possible in a total of 106 arteries; a graft was necessary for 60 arteries; and in 29 cases, the first branch had to be divided (Table 6).

The advisability of this procedure to lengthen the initial free segment seems questionable; if division of 'disturbing' branches is proscribed, a total of 89 grafts would be used, and bilateral grafting would become necessary in 7 cases in group 1 and 10 in group 2.

Additional problems with the coronary arteries may also arise after completion of the anatomical correction, as apparently satisfactory anastomoses may become twisted as a result of the dynamics of the beating working heart.

It is most probable that, because of the risks inherent in coronary artery reimplantation, the technique of aortopulmonary fenestration will be preferable (Planché, 1976).

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